A WIRE POSITION MONITOR SYSTEM FOR SUPERCONDUCTING CRYOMODULES AT FERMILAB*

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Abstract

Fermilab is jointly developing capabilities in high gradient and high Q superconducting accelerator structures. Based on the 1.3 GHz INFN/TESLA design [1-4], a wire-position-monitor (WPM) system is integrated to monitor cavity alignment and cold mass vibrations. The system consists of a reference wire carrying a 325 MHz signal, 7 stripline pickups (per cryomodule, 12-m long), and read-out electronics using direct digital signal down-conversion techniques. We present technical details of the system, and preliminary results on resolution and stability measured at a mock-up test stand.

Figure 1: The first cryomodule being moved to the cave.

WPM PRINCIPLE

Fermilab is building up a SCRF test facility. It consists 3 INFN/TESLA style cryomodules (see Figure 1), each incorporates 7 WPMs, at each end, at the three posts and between the posts.

Figure 2: Picture of the WPM at one end.

As shown in Figure 2, a WPM is a coaxial tube with four 50-Ω microstrip pickups spaced 90° apart. The IF wave on the center wire induces signals on the pickups through space coupling. While the wire's position in space is determined by its two ends, a WPM may move or vibrate with the cryomodule body. This relative displacement (in the transverse plane) between a WPM and the center wire manifests as imbalances between the strengths of the four induced signals, and can be deducted by iterations according to:

$$I_x = \frac{V_B - V_D}{V_B + V_D}, I_y = \frac{V_A - V_C}{V_A + V_C}$$
$$x = a_{10} I_x + a_{30} I_x^3 + a_{12} y^2 I_x + \ldots, y = a_{01} I_y + a_{03} I_y^3 + a_{21} x^2 I_y + \ldots$$

where A through D denote the pickups at the top, left, bottom and right.

READOUT SYSTEM

The readout electronics is housed in a VME crate. It includes a MVME-5500 PPC processor board, a timing board and a few digital receiver boards. The timing board generates a 325 MHz CW signal and 8 clock signals, using either an external RF or an internal oscillator. The 325 MHz CW is amplified and feed to the center wire. The 8 clock signals are divided down from the 325 MHz by either 4, 8, 16 or 32. They are used to clock the digital receiver boards and can be individually phase adjusted at 8.6 ps steps. Each digital receiver board has 8 channels, handling 2 WPMs. The digital receiver boards sample the induced signals from the pickups at 40.625 MHz. Every 9918 samples are grouped to get one average making the data output rate of 4096.09 Hz. For each cycle, the system takes 16384 data samples in about 4 seconds. It then processes the data and self trigger again.

The frequency of 325 MHz is chosen for good coupling between the center wire and the pickups, and for easy handling.

The DAQ software is in C++ under VxWorks. It incorporates a client-server tool to communicate with host machines. A LabVIEW package is used to control the system and visualize the results.

TEST STAND

A test stand is set up to test the readout electronics and DAQ software (see Figure 3). It uses a thinner CuBe alloy wire, 0.5 mm diameter, about 1.1 m long. The tension is 9.07 kg. The fundamental vibrating frequency of the wire is calculated to be 104.5 Hz.

To verify the long term stability of the electronics, one average position was recorded every ~ 4 seconds over a period of about 8 hours, with the inputs to the digital receiver boards connected to test signals. It showed that the system is stable to within ~ 1 um. Over another

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similar period, the system clearly showed the instability of the amplifiers for the test signals (see Figure 4).

To verify the capability of the system as a detector for microphonic vibrations, the support table were struck, and FFTs were performed over the position data, 16384 samples for every 4 seconds (see above), with the digital receiver board inputs connected to the pickups. The 104.5 Hz fundamental frequency and the 2nd harmonic are clearly shown (see Figures 5 and 6).

Figure 3: The test stand.

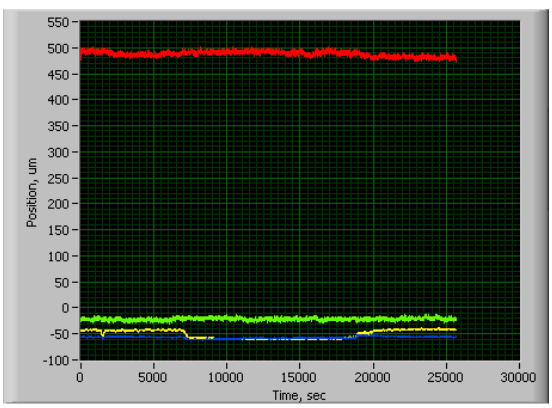

Figure 4: Positions from test signals over 7 hours.

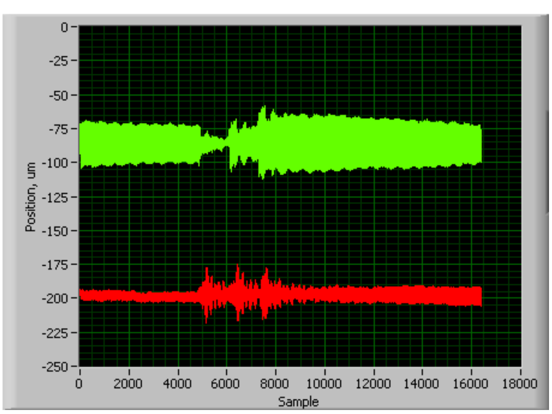

Figure 5: Positions from pickups after mechanic excitation.

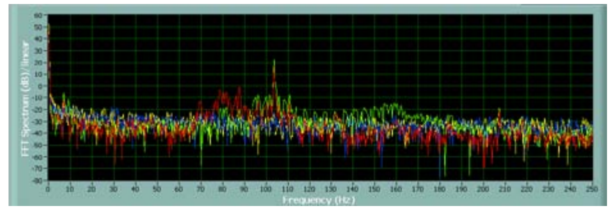

Figure 6: FFTs of the positions from pickups after mechanic excitation.

In Figure 6, 0 dB corresponds to wire displacement of 1 um, 20 dB corresponds to 10 um, -20 dB corresponds to 100 nm and so on. As can be seen the noise floor is below -20 dB, indicating the system has a special resolution of ~ 100 nm.

CONCLUSIONS

The readout electronics and software are thoroughly tested and working. The system is able to track slow drifts over long period of time with a resolution of about 1 um, and detect microphonic vibrations with a resolution of ~ 100 nm.

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